ASSIMILATION OF FY2C AMVS IN GRAPES

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Abstract

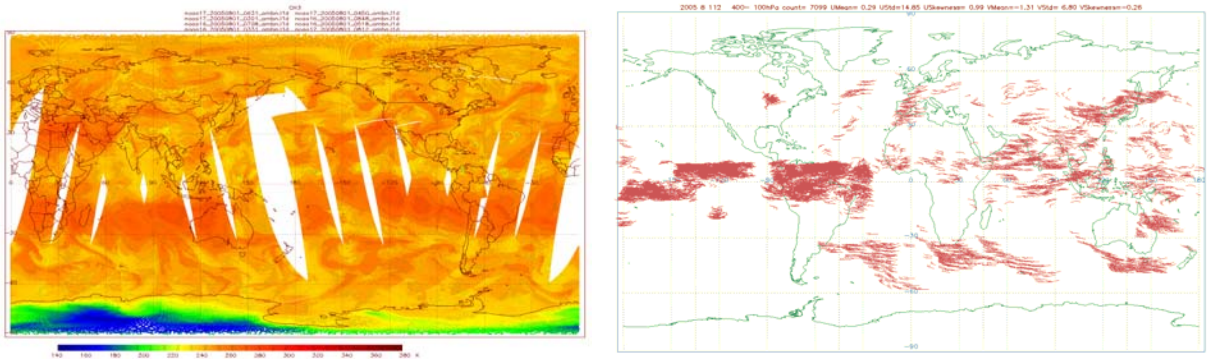
FY2C is the first operational meteorological satellite of China, which was launched on 19 Oct 2004. Since the AMV quality is an integrated result of all processing steps, with the Improvements in the image navigation and calibration algorithm, together with the improved AMV derivation scheme, the accuracy of the high density AMVs derived from FY2C is expected to be improved. There is no Quality Indicator for AMVs of FY2C as yet. The present paper describes the high density FY2C AMVs, the first guess statistics, height adjustment, quality control of FY2C AMVs and the assimilation methodology in GRAPES system. Impact trials have been conducted, showing neutral to positive impact in global forecast quality. Finally, ongoing research and future plans are also discussed.

1. INTRODUCTION

The increase of the spatial and temporal resolution of Atmospheric motion vectors (AMVs) from geostationary satellite data, together with their improved accuracy, provide excellent temporal and spatial coverage and therefore are an important input to most global and some mesoscale data assimilation systems (e.g.,Bouttier and Kelly 2001;Bormann, et al. 2003).
FY2C is the first operational geostationary meteorological satellite of China, which was launched on 19 Oct 2004. From 25 Nov 2005 on, BUFR code of FY2C AMVs is transmitted through GTS. Since AMV quality is an integrated result of many steps, starting with navigation, with the Improvements in the image navigation and calibration algorithm, together with the improved AMV derivation scheme, the accuracy of the high density AMVs derived from FY2C is expected to be improved.
In 2001, CMA (China Meteorological Administration) launched a national key-project to develop a new generation of NWP system GRAPES (Global/Regional Assimilation PrEdiction System), including variational data assimilation (3DVAR, 4DVAR), regional meso-scale numerical prediction system and global medium-range weather prediction system.
In 2005, an enhanced coordination between NSMC(National Satellite Meteorological Center) and the GRAPES R&D group is established to better understand the sources of errors entailed in the AMV processing and the requirements in the assimilation of AMVs. The present paper describes the primary results from this cooperation and ongoing research. This study investigates the height bias correction and the impact of IR winds from just FY2C on GRAPES analyses and forecasts.
This paper contains a brief overview of the GRAPES data assimilation system(section 2), a description of FY2C AMVs characteristics in general, the first guess statistics and height adjustments l(section 3). Four assimilation experiments are discussed; their aim was to give an insight into the typical impact of the height adjustment algorithm and the FY2C AMVs on the GRAPES analyses and medium-range forecast in combination with other observation types over a period of 10 days (section 4).Discussions and ongoing research is given in Section 5.

2. THE GRAPES DATA ASSIMILATION SYSTEM

The development of GRAPES is to meet the increasing requirements of meteorological services (longer period and higher accuracy of forecasts, much more detailed weather services and environmental services, …), to introduce the recent advances in atmospheric sciences, numeric, parallel computing, etc., into new operational NWP system, to enhance the close-link between scientific researches and operations, and to accelerate the transformation of new scientific and technological advances into operations, to expand the community of NWP development , including the universities and institutes, research agencies and operational centers in China.Over the past years, progresses have been made in development of GRAPES: semi-implicit and semi-Lagrangian dynamic core (unified, regional and global), full physical package, 3DVAR data assimilation system, and undergoing development of 4DVAR and EnKF. The GRAPES-3DVAR system is a new three-dimensional variational data assimilation system. GRAPES-4DVAR and GRAPES-EnKF is also in progress. In 2006, the regional version of GRAPES will be operationally running in National Meteorological Center of China. The global version of GRAPES is scheduled to be operated in the next year in the National Meteorological Center of China.



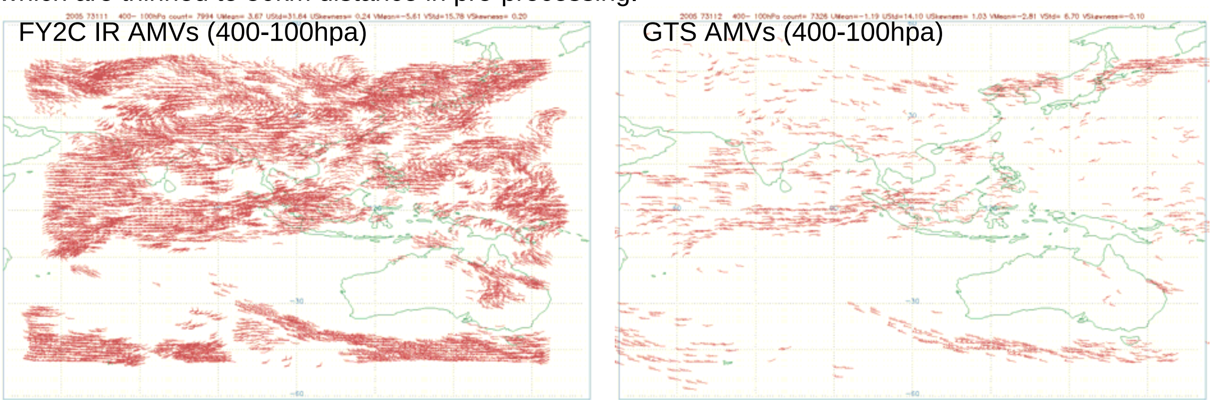
a) b)

Figure 1: **An example of satellite data assimilated in GRAPES. a) ATOVS data, b)AMV data.**

Two main types of satellite observation assimilation has been developed in GRAPES-3DVAR, includingv ATOVS radiances from polar orbit satellite and AMVs from geostationary satellite, as shown in Figure 1. In the present GRAPES 3DVAR, AMV is treated as conventional upper-air wind observations, that is , as a single-level observations.

3. FY2C AMV WINDS

NSMC developed its own AMV scheme. This total automatic scheme had been performed in operation with GMS5 data from January 1997 to April 2003. In the process of calculating AMVs with FY2 data, it is noticed that high quality pre-processing is essential. A big effort is then made at improving fundamental data preprocessing quality. Navigation accuracy for FY2C image reaches pixel level.At the same time, the scheme itself is also improved(Xu et al.,2004). An example of the high density AMVs in high level(400-100hpa),mid-level(700-400hpa) and low level(1000hpa-700hpa) derived from FY2C are shown in Figure2, comparing with AMVs from other geostationary satellite through GTS which are thinned to 50km distance in pre-processing.



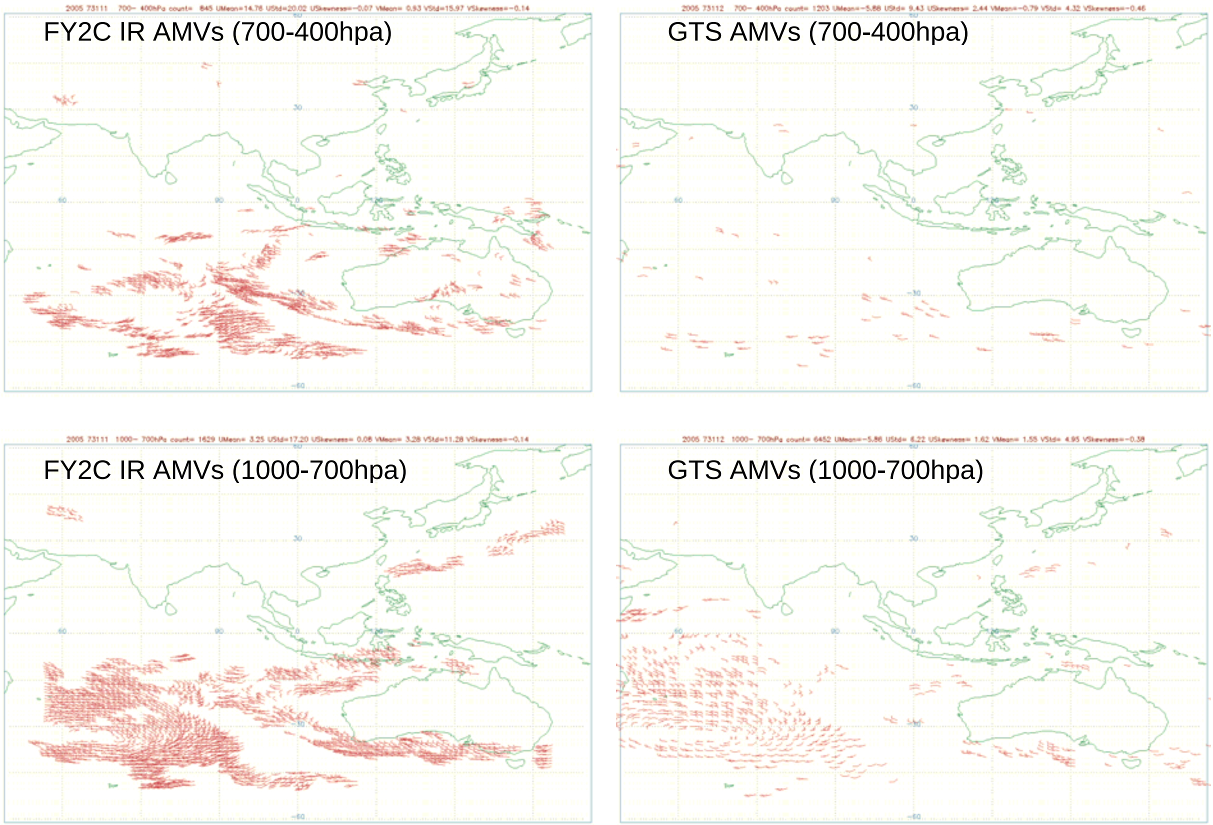


Figure 2: **Example of high density FY2C IR AMVs coverage at high (400-100hpa), mid (700-400hpa) and low (1000-700hpa) level on 31 July 2005 at 0012 UTC in comparision with AMVs from GTS .**

It can be seen that the FY2C AMVs provide an excellent coverage in a region otherwise poorly sampled by the conventional observing network, such as western Pacific and Indian Ocean. Comparing with AMVs from other geostationary satellite through GTS, the spatial resolution of FY2C AMVs seems be more higher. On 31 July 2005 at 00112 UTC, typhoon MATSA which affected China greatly was at 134.0^{o}E,11.7^{o}N. The high level divergence flow can be clearly seen near 134.0^{o}E,11.7^{o}N in Figure 3. In another region near 115^{o}E,45^{o}N, the high level convergence flow is very clear in the FY2C IR AMVs. Although the accuracy of AMVs is not easy to make a conclusion, FY2C AMV have its own characteristics and need to be studied further to make an effective use of this wealth information, especially over the data-void region in terms of conventional observations.

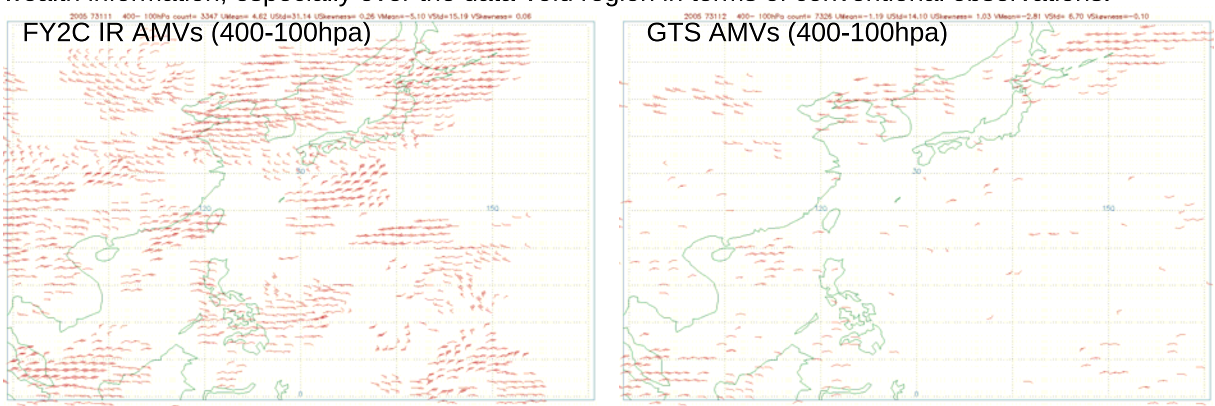
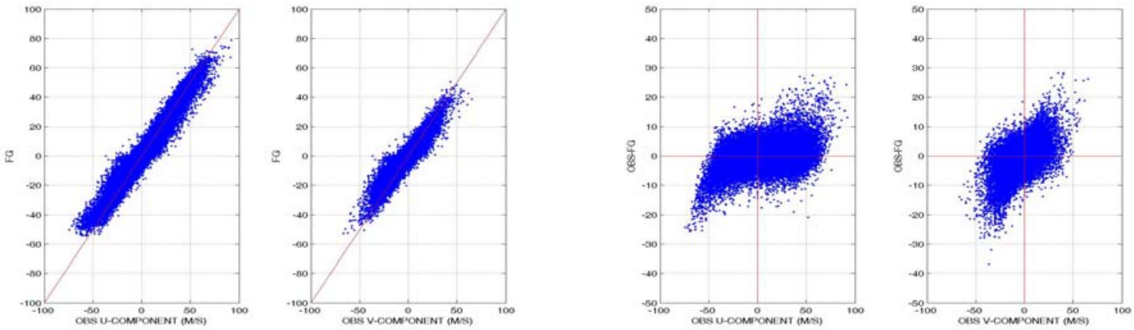


Figure 3: **A example of high density FY2C IR AMVs (400-100hpa) in comparision with AMVs from GTS .**

3.1 First Guess Statistics for FY2C AMVs

A good specification of the random and systematic errors of any observation is essential in order to extract information from the observation in an assimilation system in a near-optimal way(Bormann et al.,2003). The errors assigned to the observations together with an estimate for the error in the first guess fields determine the weighting of both in the analysis system and therefore which features are assimilated from the observations. The statistics of innovation of FY2C IR AMVs is monitoring on the analysis time of UTC 0012Z over the period 1-15 August 2005.

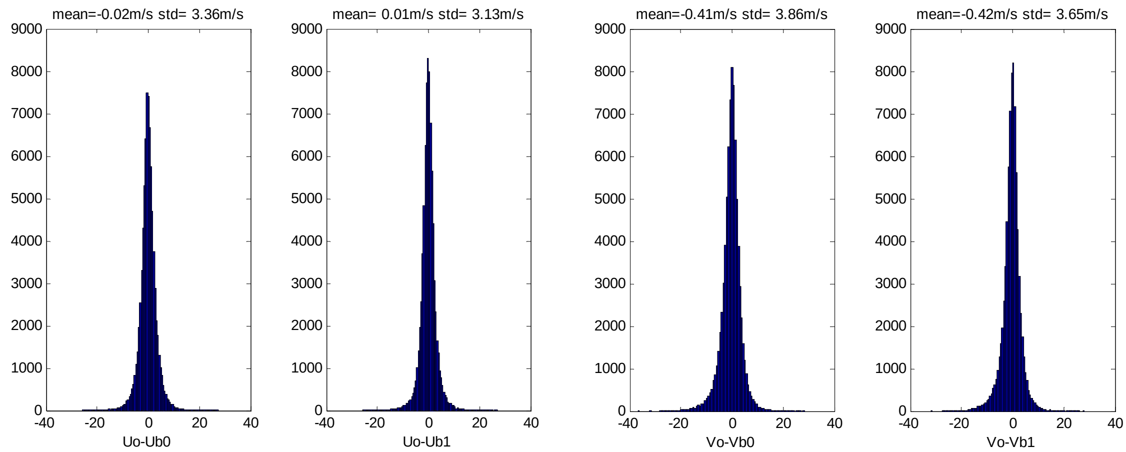


a) b) c) d)

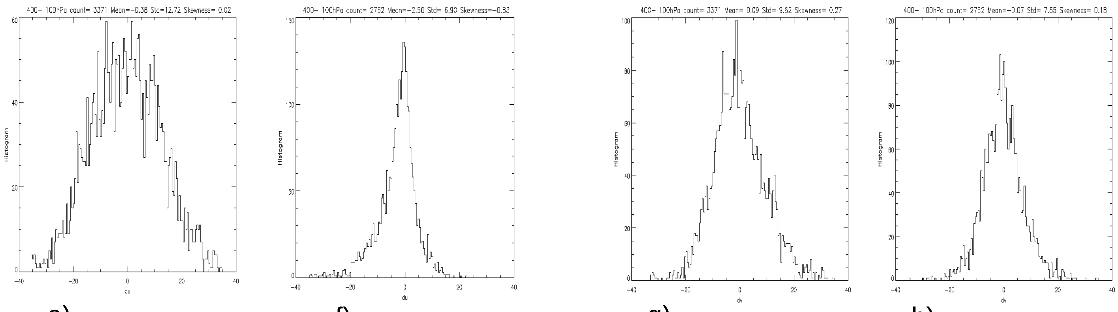
Figure 4: **FY2C IR AMVs against T213 background. a) and b) are the scatter plots of the U, V components of FY2C IR AMVs against T213 background for FY2C IR at all level between 60S and 60N for 1-15 August 2005 on 0012Z UTC respectively, c) and d) are the scatter plots of OBS minus FG against OBS for U,V components respectively.**

There is no Quality Information as yet in FY2C AMVs. All the IR AMVs are monitoring in this study. The monitoring is against the first guess (the background) which is the 12h forecast of the operational T213 model running in National Meteorological Center (NMC) of CMA at present. No strong slow bias was found in this monitoring, the scatter plots(Figure 4a,b) are fairly evenly distributed about the 1:1 line, although there are a slight tendency of fast bias on the fast FY2C winds as shown in Figure 4c,d.

3.2 Height Adjustments Before Assimilation



a) b) c) d)



e) f) g) h)

Figure 5: **Innovation histogram of FY2C IR AMVs before and after height adjustment. a) and c) are for u and v component respectively before height adjustment; b) and d) are for u and v component respectively after height adjustment. e),f),g) and h) are for a case at 0012Z UTC on 31 July 2005, e) and g) are for u and v component respectively before height adjustment; f) and h) are for u and v component respectively after height adjustment.**

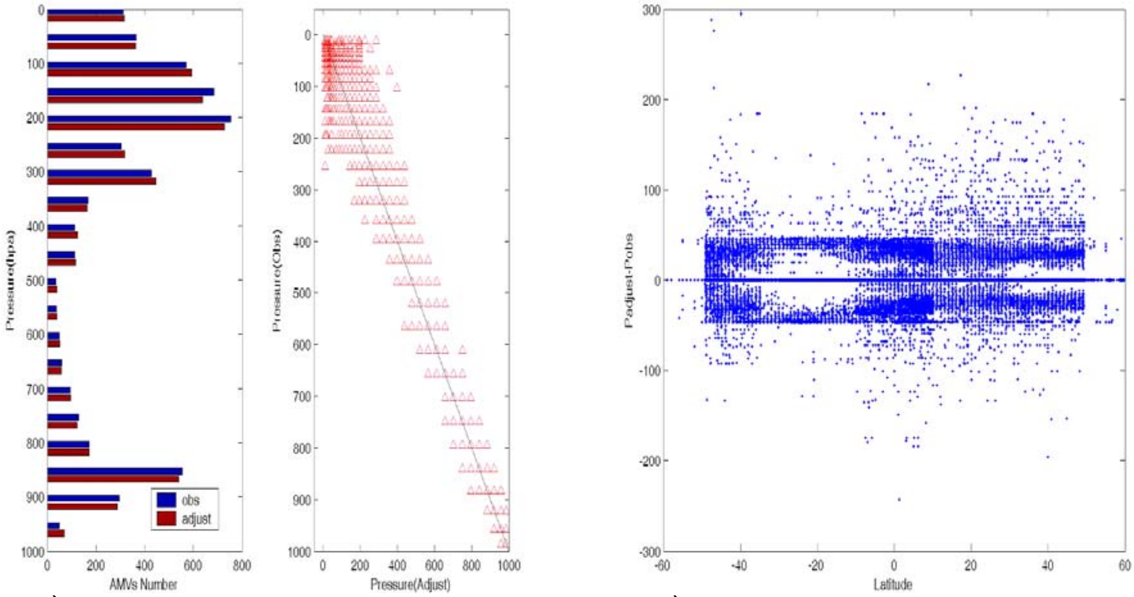
Despite the generally positive impact of the AMVs in global NWP, their use remains difficult because of systematic height assignment errors(Rao et al.,2002). Errors in the height assignment of some satellite-derived winds exist because the satellites sense radiation emitted from a finite layer of the atmosphere rather than a specific level. Studies of what does the wind actually represents have a lot of potential to improve the use of AMVs in NWP and assimilation systems. Problems in data assimilation may arise because the motion of a measured layer is often represented by a single-level value. In the present GRAPES 3DVAR, AMV is as a single-level observations. Good AMVs often get rejected in the pre-processing for NWP models because of too large a difference to the model background. A quality indicator for height assignment is expected to help the better use of AMVs and additionally to reduce the dependency on model fields or observations in quality control .

In the present study, it was decided to adjust the “observed” pressure of the winds by the minimization of a simple cost function J which measures the discrepancy between the AMV data and the model first guess corresponding values:

$$J(p)=\frac{1}{2}\left[\left(\frac{u_o-u_b(p)}{U_e}\right)^2+\left(\frac{v_o-v_b(p)}{V_e}\right)^2+\left(\frac{p-p_o}{P_e}\right)^2\right], \qquad (1)$$

Where u_o v_o and $u_b(p)$, $v_b(p)$ are the observed and first-guess values of wind components, p and p_o are the optimal adjusted pressure and the AMV pressure assignment, U_e, V_e, P_e are uncertainty of wind components and height assignment respectively. In the present study, it was set that $U_e = 3.0m/s$, $V_e = 2.0m/s$, $P_e = 50hpa$ .These parameters depend on the observation uncertainty and the background uncertainty and need to be tuned in further. This pre-processing step has led to a more similar to Gaussian distribution of the observation innovations (Fig.5), which is more optimal in the variational framework. The usefulness of the height adjustment step has been also confirmed by experiments shoen in Section4, with and without the height corrections, especially in Northern Hemisphere where the background is better.

The scatter plot(Fig. 6b) is fairly evenly distributed about the 1:1 line, although there is a slight tendency to decrease the height of the higher level winds, especially for AMVs between 200hpa and 150hpa(Fig.6a,6c). Most winds are moved less than 100 hPa, but there are some, particularly at high level, which are moved by 250 hPa or more(Fig. 6c). A very interesting result is that the height adjustments of AMVs demonstrates a dependency on latitude (Fig. 6c).From 5^{o}S to 25 ^{o}N, the adjustments are more continuous, whereas the adjustments are discontinuous in the mid-latitude, especially in the Southern Hemisphere(10^{o}S to 30 ^{o}S).What does it imply? Is it related to the strong vertical shear in the mid-latitude? The reasons are still under investigation.



a) b) c)

Figure 6: **Height adjustment of FY2C IR AMVs for 15 days(1-15 August 2005). Figure 6a is the average vertical distribution of AMVs at 1200Z UTC, binned every 50mb before and after height adjustment, Figure 6b is scatter plot of adjusted pressure against unadjusted pressure, Figure 6c is scatter plot of height adjustment of AMVs distribution along latitude.**

4. IMPACT STUDIES

There is no Quality Indicator for AMVs of FY2C as yet. At present, only a simple first guess quality check is performed in the quality control of FY2C IR AMVs. The observed value is compared to the value of the background field to ensure that its value is reasonable and to eliminate gross errors. For very large departures the first guess check rejects the observation. The observed wind components are checked together. If the absolute deviation above a predetermined factor multiple of its observational error, the observation is rejected. The predetermined factor is set to 1.5 in the experiments. The AMVs observational errors for wind components is similar to the Met Office NWP model, as shown in Table 1. No special asymmetric check(Forsythe et al.,2005) is applied since no slow bias was found in FY2C AMVs in the first guess statistics as shown in Section 3.

Level (hPa)	1000	850	700	500	400	300	250	200	150	100	70
Error (m/s)	3.6	2.8	4.0	4.8	6.2	6.2	5.6	5.8	6.6	11.8	11.8

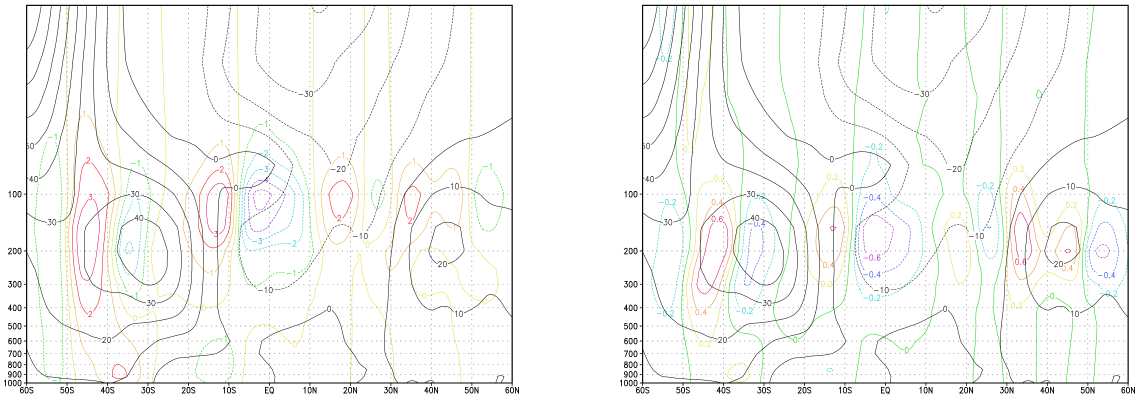
Table 1: **I The observational errors setting in GRAPES for FY2C AMVs.**

Two pairs of data assimilation experiments were undertaken to investigate the impact of FY2C AMVs and the height adjustment on GRAPES global model analyses and forecasts. All experiments use GRAPES 3DVAR without cycle(e.g. assimilate observations only once at the analysis time) and the first guess (the background) is the 12h forecast of the operational T213 model running in National Meteorological Center (NMC) of CMA. After assimilation, a 6-day forecast was run from each 12Z analysis over the period 1-10 August 2005.In order to verify the forecast to its own analysis, another 6 assimilations are performed over the period 11-16 August 2005 at 0012Z UTC.

The forecast model is GRAPES Global Model, with horizontal resolution: 0.5 x 0.5 degrees, 31 vertical levels. The first pair of experiments is mainly to investigate the impact of height adjustments, where only FY2C IR AMVs are assimilated. The second pair of experiments is to investigate the impact of the FY2C AMVs with and without height adjustments in a quasi-operational forecast system, where the upper-air observations and synoptic observations are also assimilated. The two pairs of experiments are shown in Table 2,where FY2C(NoHA) represents FY2C IR AMVs without height adjustments, FY2C(HA) represents FY2C IR AMVs with height adjustments, TEMP represents for the upper-air observations, SYNOP represents for the synoptic observations.

1ST PAIR EXPERIMENTS		2nd PAIR EXPERIMENTS	
Exp.1	xb(T213 12h Forecast)	Exp.4	xb+TEMP+SYNOP
Exp.2	xb+FY2C(NoHA)	Exp.5	xb+TEMP+SYNOP+FY2C(NoHA)
Exp.3	xb+FY2C(HA)	Exp.6	xb+TEMP+SYNOP+FY2C(HA)

Table 2: **The two pairs of data assimilation experiments.**



a) b)

Figure 7: **a) Vertical distribution of difference between the mean zonal wind (60°E-160°E) analyses for the August FY2C IR AMVs without height adjustment, along latitude, over period 2005080112-2005081512,at every 0012Z UTC, the black contours denote the mean background, the colour contours denote the increments. b) As in a),but for the experiments with height adjustment.**

4.1 Impact on Wind Analysis

The impact on analysis is performed over a period over 15 cases (2005080112-2005081512,at every 0012Z UTC). The mean zonal wind field (along 60°E-160°E) reveals a substantial strengthening of the equatorial easterly jet over the tropics and as a result of assimilating FY2C AMVs (Fig. 7). Furthermore, more detailed synoptic scale structures are found in the subtropical jets. Differences between the mean wind analyses of the experiments with and without FY2C winds reach 5 m/s without height adjustments, whereas 0.6 m/s with height adjustments.
It is also noted that the height of analysis increments decrease as the height of the higher level winds decrease with height adjustment(Fig. 6). At present, it is difficult to evaluate whether the analysis increments is a realistic feature.

4.2 Forecast Impact

Fig. 8 shows scores for the geopotential scores from a validation of each experiment against its own analysis (This avoids penalizing the experiments without FY2C winds). In the first pair of experiments, it is demonstrated that the height adjustments leads to a positive impact on 6 days forecast scores over the Northern Hemisphere, whereas a positive impact on 2 days forecast scores over the Southern Hemisphere. In the second pair of experiments, the inclusion of FY2C winds with height adjustment has a positive impact on forecast scores over the Northern Hemisphere, and the inclusion of FY2C winds without height adjustment has a positive impact over the Southern Hemisphere.

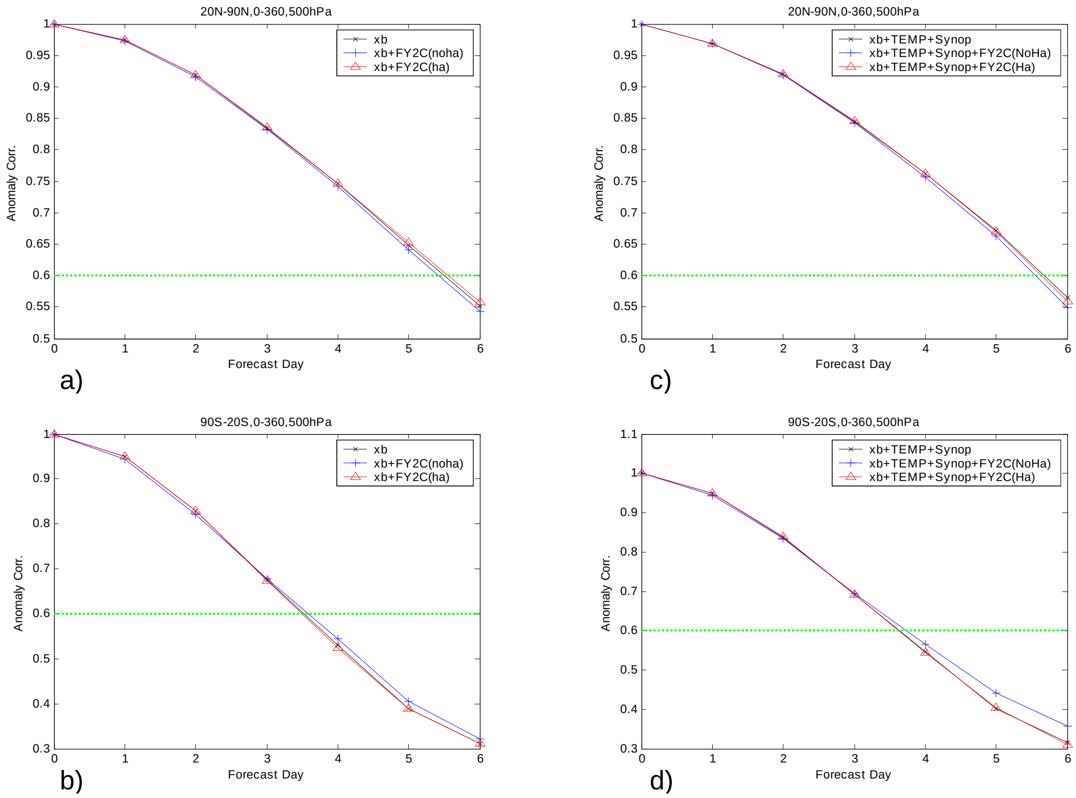


Figure 8: **Anomaly correlation for the geopotential forecast from the experiment, Exp.1(black line with asterisk), Exp.2 (blue line with plus sign) Exp.3 (red line with triangle sign). a) and b) show scores for the Northern and the Southern Hemisphere at 500hPa respectively in the first pair of experiments, c) and d) show scores for the Northern and the Southern Hemisphere at 500hPa respectively in the second pair of experiments The forecasts have been validated against its own analysis.**

Fig. 9 show the root mean squared forecast errors for the wind field for the second pair of experiments. The inclusion of FY2C winds with height adjustment has a positive impact over the Northern and Southern Hemisphere and Tropics. The reduction of wind forecast errors is relatively small, but nevertheless statistically significant. A particularly strong positive forecast impact can be reported for scores over the region(60^{o}S-60^{o}N,60^{o}E-180^{o}E) where FY2C cover, as shown in Fig. 9d.

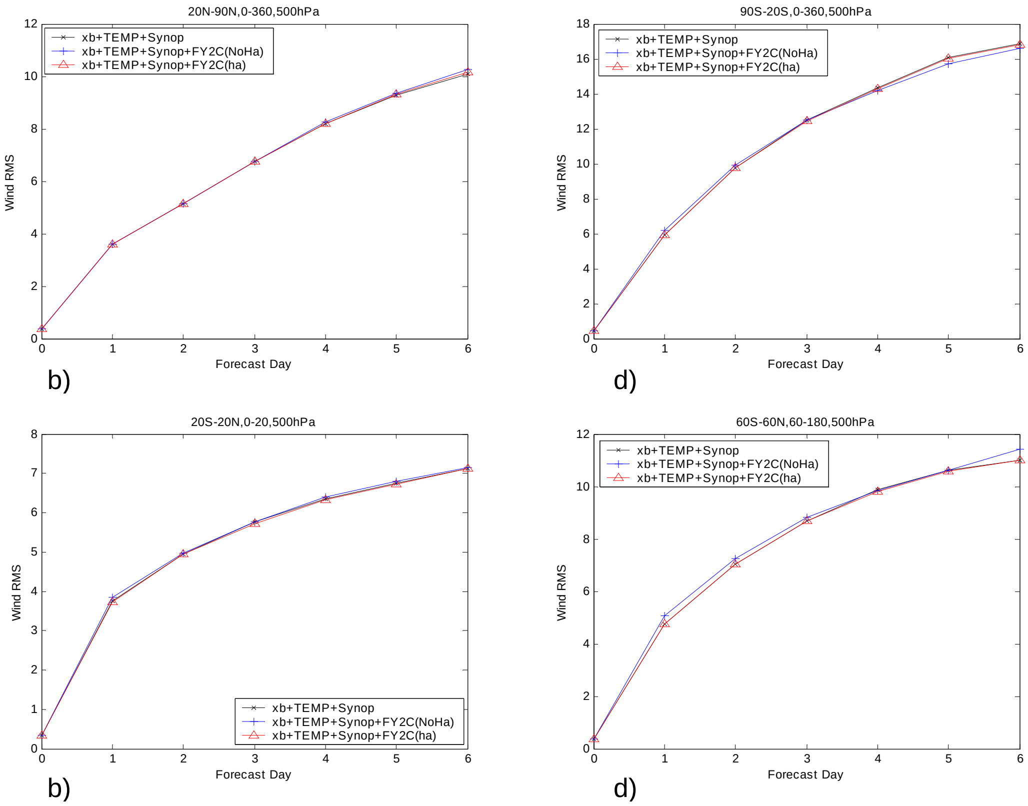


Figure 9: **Root mean squared forecast errors for the wind field for the second pair of experiments, Exp.4(black line with asterisk), Exp.5 (blue line with plus sign) Exp.6 (red line with triangle sign). a) and c) show scores for the Northern and the Southern Hemisphere at 500hPa respectively in the second pair of experiments, b) and d) show scores for tropics and the region of FY2C coverage(60^{O}S-60^{O}N,60^{O}E-180^{O}E) at 500hPa respectively . The forecasts have been validated against its own analysis.**

5. DISCUSSIONS AND ONGOING RESEARCH

The impact of FY2C AMVs on GRAPES analyses and forecasts has been investigated by performing data assimilation experiments with and without these winds over 10 cases. The height uncertainty is still a problem. The present height adjustment algorithm depends heavily on the background. More information needed about quality of height assignment and backgroud. Ongoing researches are:

- Two months experiments(20050801-20050831,20060201-20060228) are being undertaken;
- Tuning of the height adjustment parameters to reflect the current data characteristics and background;
- Investigation of the horizontal correlated errors and scales of FY2C AMVs;
- Monitoring and assimilation of cloudy water vapor winds from FY2C in GRAPES.

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